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(54) **Method for controlling the melting points and molecular weights of syndiotactic polyolefins using metallocene catalyst systems**

Verfahren zur Kontrolle des Schmelzpunktes und Molekulargewichtes von syndiotaktischen Olefinpolymeren unter Anwendung eines Metallocen-Katalysatorsystems

Procédé de réglage des points de fusion et des poids moléculaires de polyoléfines syndiotactiques en utilisant des systèmes catalytiques métallocènes

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**EP-A- 0 563 834**

• **DATABASE WPI Derwent Publications Ltd.,**  
**London, GB; AN 92-127296 'new transition metal**  
**compounds having high cristallisation speed' &**  
**JP-A-4 069 394 (MITSUI TOATSU CHEMICALS)**  
• **DATABASE WPI Derwent Publications Ltd.,**  
**London, GB; AN 93-061652 'catalysts for mfr of**  
**syndiotactic poly-alpha-olefins' & JP-A-5 009**  
**213 (MITSUI TOATSU CHEMICALS)**

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**EP 0 577 581 B1**

## Description

BACKGROUND OF THE INVENTION

## 5 TECHNICAL FIELD:

**[0001]** The present invention provides a method for varying the melting points and molecular weights of syndiotactic polyolefins in a process of polymerization using metallocene catalysts. The catalysts used in the present invention are stereorigid and include a bridge between sterically different cyclopentadienyl groups. It has been discovered that  
10 addition of substituents to the aryl rings in the fluorene ligand of one cyclopentadienyl ring influences melting point and molecular weight of syndiotactic polyolefins produced with these metallocene catalysts.

**[0002]** The present invention relates to the use of metallocene catalysts in the production of polyolefins, particularly polypropylene, and the ability to vary certain properties of the polymer products by varying the structure of the catalyst. In particular, it has been discovered that position of substituents on the aryl rings of fluorene ligand in the metallocene  
15 catalyst changes the melting points and the molecular weights of the polymer products.

## DESCRIPTION OF THE PRIOR ART:

**[0003]** Transition metal catalysts in the form of metallocenes have been known for some time, but up until just recently, such catalysts could only produce predominantly atactic polymer which is not nearly as useful as the crystalline forms, isotactic and syndiotactic polymers. It was discovered that by attaching a bridge between the cyclopentadienyl rings in a metallocene catalyst and by adding one or more substituents on the rings to make the compound both stereorigid and chiral, a high percentage of isotactic polymer could be produced. On the other hand, stereorigid metallocenes derived from achiral ligands containing differently substituted cyclopentadienyl rings connected by a bridge produced a high percentage of syndiotactic polymer.  
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**[0004]** The use of metallocenes as catalysts for the polymerization of ethylene is known in the art. German patent application 2,608,863 discloses a catalyst system for the polymerization of ethylene consisting of bis(cyclopentadienyl)-titanium dialkyl, an aluminum trialkyl and water. German patent application 2,608,933 disclosed an ethylene polymerization catalyst system consisting of zirconium metallocenes of the general formula (cyclopentadienyl)<sub>n</sub> Zr Y<sub>4-n</sub>, wherein  
30 Y represents R<sub>1</sub>CH<sub>2</sub>AlR<sub>2</sub>, CH<sub>3</sub>CH<sub>2</sub>AlR<sub>2</sub> and CH<sub>3</sub>CH (AlR<sub>2</sub>)<sub>2</sub> wherein R stands for an alkyl or metallo-alkyl, and n is a number within the range 1-4; and the metallocene catalyst is in combination with an aluminum trialkyl cocatalyst and water.

**[0005]** The use of metallocenes as catalysts in the copolymerization of ethylene and other alpha-olefins is also known in the art. U.S. Patent No. 4,542,199 to Kaminsky, et al. disclosed a process for the polymerization of olefins and particularly for the preparation of polyethylene and copolymers of polyethylene and other alpha-olefins. The disclosed catalyst system includes a catalyst of the formula (cyclopentadienyl)<sub>2</sub>MeRHal in which R is a halogen, a cyclopentadienyl or a C<sub>1</sub>-C<sub>6</sub> alkyl radical, Me is a transition metal, in particular zirconium, and Hal is a halogen, in particular chlorine. The catalyst system also includes an aluminoxane having the general formula Al<sub>2</sub>OR<sub>4</sub>(Al(R)-O)<sub>n</sub> for a linear molecule and/or (Al(R)-O)<sub>n+2</sub> for a cyclic molecule in which n is a number from 4-20 and R is a methyl or ethyl moiety. A similar  
40 catalyst system is disclosed in U.S. Patent No. 4,404,344.

**[0006]** U.S. Patent No. 4,530,914 discloses a catalyst system for the polymerization of ethylene to polyethylene having a broad molecular weight distribution and especially a bimodal or multimodal molecular weight distribution. The catalyst system is comprised of at least two different metallocenes and an alumoxane. The patent discloses metallocenes that may have a bridge serving to make the rings stereorigid. The bridge is disclosed as being a C<sub>1</sub>-C<sub>4</sub> alkylene radical, a dialkyl germanium or silicon, or an alkyl phosphine or amine radical.  
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**[0007]** European Patent Application 0185918 discloses a stereorigid, chiral metallocene catalyst for the polymerization of olefins. The bridge between the cyclopentadienyl groups is disclosed as being a linear hydrocarbon with 1-4 carbon atoms or a cyclical hydrocarbon with 3-6 carbon atoms. The application discloses zirconium as the transition metal used in the catalyst, and linear or cyclic alumoxane is used as a co-catalyst. It is disclosed that the system produces a polymer product with a high isotactic index.  
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**[0008]** Japanese patent application n° JP4069394 discloses transition metal compounds prepared by adding lithiated isopropylidene (cyclopentadiene-2, 7-di-tert-butyl-9-fluorene)di-lithium to zirconium tetrachloride in order to produce syndiotactic poly-alpha-olefins having a high crystallization speed.

**[0009]** European patent application n° 92202638.0 discloses a process for the preparation of a bridged metallocene compound in which :  
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- 1) a bridged double ligand, reacting with a proton acceptor, is converted into a bridged double anion;
- 2) the double anion is converted into the bridged metallocene compound through reaction with a compound of a

group 4b, 5b or 6b metal from the Periodic System of Elements, reaction 2) being carried out in a liquid dispersant which

a) comprises one or more weak Lewis bases, the conjugated acid of which has a dissociation constant  $pK_a$  for which the following holds:

$$pK_a < \text{or} = -2.5,$$

b) contains at most 1 mole equivalent, relevant to the metal compound, of strong Lewis base, the conjugated acid of which has a  $pK_a$  that is higher than -2.5.

It discloses explicitly the bridged metallocene compound 2,2-propyl(1-dimethylamino-9-fluorenyl)(1-cyclopentadienyl)zirconium dichloride. It further relates to a catalyst component for the polymerization of olefins.

**[0010]** It is known that polyolefins, and principally polypropylene, may be produced in three primary forms: isotactic, syndiotactic and atactic, the first two being crystalline and the latter being amorphous. While it is possible for a catalyst to produce all three types of polymer, it is desirable for a catalyst to produce predominantly isotactic or syndiotactic polymer with very little atactic polymer. U.S. Patent No. 4,892,851 discloses a metallocene catalyst for use in preparing syndiotactic polyolefins. The catalyst comprises a bridged metallocene in which one of the cyclopentadienyl rings is substituted in a substantially different manner from the other ring. It was discovered that this type of catalyst is highly syndiospecific, and it also produces a polymer with a novel microstructure. The invention further includes the use of one or more of the catalysts in a polymerization process.

**[0011]** The catalyst is generally described by the formula:  $R''(CpR_n)(CpR'_m)MeQ_k$  wherein each Cp is cyclopentadienyl or substituted cyclopentadienyl ring; each  $R_n$  and  $R'_m$  is the same or different and is a hydrocarbyl radical having 1-20 carbon atoms;  $R''$  is a structural bridge between the two Cp rings imparting stereorigidity to the catalyst; Me is a group 4b, 5b or 6b metal from the Periodic Table of Elements; each Q is a hydrocarbyl radical having 1-20 carbon atoms or is a halogen;  $0 \leq k \leq 3$ ;  $1 \leq m \leq 4$ ;  $0 \leq n \leq 4$  and wherein  $R'_m$  is selected such that  $(CpR'_m)$  is a sterically different ring than  $(CpR_n)$ . The present invention further discloses that the catalyst structure affects the properties of a syndiotactic polymer. It is believed the invention would be effective for all predominantly crystalline polymer from olefins of three or more carbon atoms.

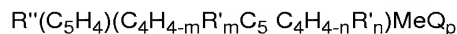
**[0012]** The present invention relates to discoveries made as to varying substituents added to the aryl rings in the fluorene ligand in a metallocene catalyst on the polymerization of propylene and higher  $\alpha$ -olefins. In particular, it was discovered that by varying these components, the physical properties of the polymer may be controlled.

#### SUMMARY OF THE INVENTION

**[0013]** It was discovered that the addition of various substituents on the aryl rings of the fluorene ligand varied the melting point of a polyolefin. This is a significant discovery, as heretofore it was the commercial practice to vary the melting points of polymer products by co-polymerizing varying amounts of ethylene to produce co-polymers with a range of differing melting points. It is desirable to produce a homopolymer with varying melting points without the use of ethylene. The present invention provides a method for the production of homo-polymers with varying melting points by varying the structure of the metallocene catalyst used in the polymerization.

**[0014]** Similarly, it was discovered that by changing the substituents on the aryl rings of the fluorene ligand of a metallocene catalyst, polymers are produced with different molecular weights. Thus, the molecular weight of the polymer product may be controlled by changing the substituents in the catalyst. Accordingly, the present invention provides a method for varying both the melting point and the molecular weight of a polymer product.

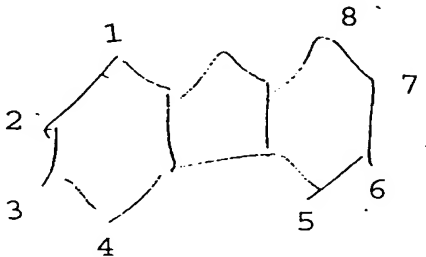
**[0015]** The present invention also provides a process for the polymerization of olefins comprising contacting an organoaluminum compound with a metallocene described by the formula:



wherein  $(C_5H_4)$  is a cyclopentadienyl ring;  $(C_4H_{4-m}R'_mC_5C_4H_{4-n}R'_n)$  is a fluorenyl radical;  $R'$  is a hydrocarbyl radical, an alkoxy, an alkoxy alkyl or an alkylamino radical, having from 1-20 carbon atoms or a halogen, each  $R'$  may be the same or different;  $R''$  is a structural bridge between the  $(C_5H_4)$  and  $(C_4H_{4-m}R'_mC_5C_4H_{4-n}R'_n)$  rings to impart stereorigidity and, preferably, is an alkylene radical having 1-4 carbon atoms, a silicon hydrocarbyl compound, a germanium hydrocarbyl compound, an alkyl phosphine, an alkyl amine, a boron compound or an aluminum compound and may contain any of these and other hydrocarbyl groups to form the bridge; Q is a hydrocarbon radical such as an alkyl, aryl, alkenyl, alkylaryl or arylalkyl radical having 1-20 carbon atoms or is a halogen; Me is a Group IIIB, IVB, VB, or VIB metal as positioned in the Periodic Table of Elements;  $1 \leq m \leq 4$ ;  $0 \leq n \leq 4$ ; and p is the valence of Me minus 2, wherein  $R'$  is

an electron donating substituent on the fluorene ligand at C<sub>2</sub> or C<sub>3</sub> and has the ability to donate electrons equal to or greater than that for t-butyl.

**[0016]** The metallocene structure is given below:



The preferred positions of R' include C2 or C3.

The selection of substituents for fluorene is based on the steric bulk as well as their ability to donate or withdraw electrons, either inductively or through resonance. These substituents include alkyl and aryl groups and heteroatom containing groups such as halogens, alkoxy groups, alkylamino groups and alkyl derivatives containing Group IVB elements such as silicon, germanium and tin.

**[0017]** An olefin monomer is added to the metallocene catalyst and the organoaluminum compound. After the polymerization has taken place, the polymer product is withdrawn. The process is characterized by the fact that it provides control of the melting point of the polymer product by controlling the number of inversions in the xylene insoluble fraction of the polymer. The number of inversions are effected by the R' group. Thus, the melting point of the polymer product may be varied and controlled by varying the R' substituents on the aryl rings of the fluorene ligand of the metallocene.

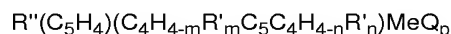
**[0018]** It was discovered that for a given substituent on the fluorene, the polymer yield (catalyst efficiency) and polymer properties, such as melting point and molecular weight, depended on the site of substitution. It was also discovered that for a given site of substitution on fluorene, the polymer yield and the polymer properties, such as molecular weight and melting point, depended on the nature of the substituents. Furthermore, it was discovered that the effects on polymer properties of different kinds of substituents on the fluorene ring are additive.

### DETAILED DESCRIPTION OF THE INVENTION

**[0019]** The present invention provides a method of controlling the melting point of a polymer by controlling the number of inversions in the chain of the xylene insoluble fraction of the polymers. The number of inversions are controlled in turn by the structure and composition of the catalyst, and the number of inversions and hence the melting point of the polymer product may be controlled and varied by varying the catalyst. In particular, it has been discovered that varying the R' substituents on the aryl rings of the fluorene ligand will vary the melting point. In addition, it has been discovered that varying the substituents on the aryl rings of the fluorene ligand in the catalyst will also vary the molecular weights of the polymer products. These beneficial advantages will become more apparent from the following detailed description of the invention and the accompanying examples.

**[0020]** Normally, when propylene, or another alpha-olefin, is polymerized with a catalyst system prepared from a transition metal compound, the polymer comprises a mixture of crystalline hydrocarbon insoluble and amorphous hydrocarbon soluble fractions which may be separated using suitable solvents. As described by the present invention, the composition and location of the substituents added to the ligand affect the properties of the polymer such as melting points and molecular weights.

**[0021]** The metallocene catalyst as used in the present invention must be stereorigid but may be chiral or achiral. Rigidity is achieved by an interannular bridge. The catalyst may be described by the formula:



wherein (C<sub>5</sub>H<sub>4</sub>) is a cyclopentadienyl ring and (C<sub>4</sub>H<sub>4-m</sub>R'<sub>m</sub>C<sub>5</sub>C<sub>4</sub>H<sub>4-n</sub>R'<sub>n</sub>) is a fluorenyl radical; R' is a hydrocarbyl radical, an alkoxy, an alkoxy alkyl or an alkylamino radical having from 1-20 carbon atoms or a halogen, each R' may be the same or different; R'' is a structural bridge between the (C<sub>5</sub>H<sub>4</sub>) and (C<sub>4</sub>H<sub>4-m</sub>R'<sub>m</sub>C<sub>5</sub>C<sub>4</sub>H<sub>4-n</sub>R'<sub>n</sub>) rings to impart stereorrigidity and, preferably, is an alkylene radical having 1-4 carbon atoms, or arylalkyl or diaryl alkyl radical containing 7-20

carbon atoms, a silicon hydrocarbonyl compound, a germanium hydrocarbonyl compound, an alkyl phosphine, or an alkyl amine; Q is a hydrocarbon radical, such as an alkyl, aryl, alkenyl, alkylaryl or arylalkyl radical having 1-20 carbon atoms, or is a halogen; Me is a Group IIIB, IVB, VB, or VIB metal as positioned in the Periodic Table of Elements;  $1 \leq m \leq 4$ ;  $0 \leq n \leq 4$ ; and p is the valence of Me minus 2, wherein R' is an electron donating substituent on the fluorene ligand at C2 or C3 and has the ability to donate electrons equal to or greater than that for t-butyl.

**[0022]** Exemplary alkylene radicals having 1-4 carbon atoms are methylene, ethylene, propylene and butylene. Exemplary hydrocarbonyl radicals are methyl, ethyl, propyl, butyl, amyl, isoamyl, hexyl, isobutyl, heptyl, octyl, nonyl, decyl, cetyl, phenyl, and the structural isomers of the alkyl groups where appropriate. Exemplary halogen atoms are fluorine, chlorine, bromine and iodine with fluorine and chlorine being preferred.

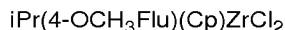
**[0023]** The preferred transition metals are Group IVB metals, such as titanium, zirconium and hafnium. Q is preferably a methyl radical or chlorine and p is preferably 2.  $(C_4H_{4-m}R'_mC_5C_4H_{4-n}R'_n)$  preferably forms a fluorenyl radical. As indicated, other hydrocarbon groups may be added to the cyclopentadienyl rings. The present invention is such that the R' substituents may be varied among any of those compounds listed in the above formula so as to provide polymer products with different properties. The preferred R' bridge components are alkenyl radicals, such as methylene, ethylene and isopropyl; diarylmethyl, such as diphenylmethyl; an alkyl silicon or a cycloalkyl silicon, such as cyclopropyl silicon, with the most preferred being isopropyl or diphenylmethyl.

**[0024]** The metallocene catalysts used in the present invention are produced using methods known in the art. The catalyst synthesis generally involves the following multi-step synthesis sequence: a) preparation of substituted fluorene; b) preparation of the ligand; c) preparation of the metallocene. Substituted fluorenes were prepared according to the published literature procedures whenever such fluorenes were not commercially available. For example, 4-methoxyfluorene, 2-dimethylaminofluorene, 2,7-dichlorofluorene, 2,7-difluorofluorene, and methylenepheneanthrene were purchased from Aldrich Chemical Company. 2,7-bis(dimethylaminofluorene) was prepared from the commercially available 2,7-diaminofluorene and trimethylphosphite using the procedure described in "J. Chem. Soc.", 2034 (1953); J. Chem. Soc., 870 (1954); and Vogel's "Text Book of Practical Organic Chemistry", 4th Edn, 1978 (p. 671). Conversion of commercially available 1-, 2-, and 3-hydroxyfluorenes to their methoxy derivatives was accomplished by reacting them with dimethyl sulphate in dimethyl sulfoxide in the presence of aqueous sodium hydroxide as described in Vogel's "Text Book of Practical Organic Chemistry", 4th Edn, 1978, P 755. 2-hydroxy fluorene was also synthesized by hydrogenation of 2-hydroxy fluorenone in the presence of 10% Pd on carbon in ethanol containing p-toluene sulfonic acid. Synthesis of 4-methyl fluorene was accomplished in two steps using standard organic transformations known in the art. First, 4-carboxyfluorene was reacted with lithium aluminum hydride to obtain 4-hydroxymethyl fluorene which was hydrogenated in ethanol in the presence of 10% Pd on carbon to give 4-methyl fluorene. Reaction of 4-hydroxymethyl fluorene described above with sodium hydride in THF followed by reaction of the sodium alkoxide with methyl iodide gave 4-methylenemethoxy fluorene. Synthesis of 2,7-dimethylfluorene from 5-methylanthranilic acid in several steps was accomplished using the procedures described in references "J. Am. Chem. Soc." 75, 2663 (1953) and "Ohio. J. Sci.", 65, 187 (1965)". Preparation of 2,7-di-t-butyl-4-methoxy fluorene from 4-methoxy fluorene was achieved by reacting the latter with 2,6-di-t-butyl-p-cresol in the presence of aluminum chloride in nitromethane as described in the reference, "Synthesis", 336 (1984).

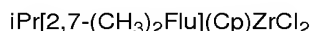
Preparation of 2,7-di-t-butylfluorene was accomplished by reacting fluorene with 2,7-di-t-butyl-p-cresol in the presence of aluminum chloride in nitromethane as described in the reference "Synthesis", 336(1984). Synthesis of 2,7-di-t-butylethynylfluorene was achieved by reacting 2,7-diiodofluorene with t-butylacetylene in the presence of organopalladium catalysts as described for similar systems in "Journal of Organic Chemistry", 48, 1854-1862, 1983.

**[0025]** The synthesis of the bridged, substituted dicyclopentadienyl ligand was accomplished by contacting fulvene or substituted fulvene with alkali metal salt of a substituted cyclopentadienyl compound of the general formula  $M[C_4H_4-mR'_mC_5C_4H_{4-n}R'_n]$  where M is Group I metal, to produce a bridged substituted dicyclopentadiene hereafter referred to as the ligand. As known in the art, fulvene is  $Cp=C$  in which a carbon atom is bound by a double bond to a cyclopentadienyl ring. Substituted fulvene as used herein is intended to mean  $Cp=CR'_a$  wherein fulvene is substituted at the terminal carbon atom with  $R'_a$  being the same or different. Conversion of the ligands to the metallocenes were performed under an inert gas atmosphere using a Vacuum Atmospheres Dry box or Shlenk techniques. The solvents were pre-dried and distilled under an inert atmosphere. The experimental procedure was described in the literature in "J. Am. Chem. Soc.", 110, 6255 (1988).

**[0026]** The following Examples illustrate methods of catalyst synthesis and procedures for obtaining a metallocene with various substituents on the fluorenyl ring. The Examples use various zirconocenes and hafnocenes to illustrate the invention but similar results would be expected for titanocene and other metallocene catalysts.

EXAMPLE 1 (outside the scope of the invention)

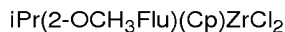
- 5 **[0027]** To a solution of  $\text{iPr[4-OCH}_3\text{Flu)Cp]}$  (2.84 g, 9.4 mmol) in 50 ml ether methyl lithium in ether (1.4 M, 20.7 mmol) was added at room temperature and stirred for two hours. Approximately 10 ml dry tetrahydrofuran (THF) were added and stirred overnight. Pentane (100 ml) was added to precipitate all the dianion and the solvents were cannulated out. The solvent traces were removed under vacuum. The residual solid was cooled to  $-78^\circ\text{C}$  and methylene chloride, prechilled to  $-78^\circ\text{C}$  (60 ml) was cannulated in. A slurry of zirconium tetrachloride (2.20 g) in methylene chloride (60 ml), prechilled to  $-78^\circ\text{C}$  was cannulated into the dianion solution. The reaction mixture was allowed to come to room temperature slowly and stirred overnight. The dark red solution was filtered and the filtrate was concentrated to 1/10 volume. A toluene/pentane mixture was added, to the concentrate which precipitated the product. The solvents were cannulated out, the product washed with toluene/pentane mixture and dried in vacuo.

15 EXAMPLE 2 (outside the scope of the invention)

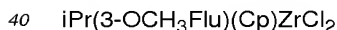
- 20 **[0028]** To an anhydrous ether (75 ml) suspension of  $\text{iPr[2,7-(CH}_3\text{)}_2\text{Flu)Cp]}$  (3.0 g, 10 mmol), methyl lithium in ether (1.4 M, 22 mmol) was added and stirred for two to four hours. Anhydrous THF (10 ml) was added and stirred for eighteen hours. The dark red solution was concentrated and dry pentane was added resulting in an orange solid precipitate. The solid was washed with twice the pentane and was suspended in 120 ml fresh pentane. A slurry of  $\text{ZrCl}_4$  in dry pentane was cannulated into the dianion suspension under argon pressure. After stirring for two hours, THF (5 ml) was added and the mixture stirred overnight. The organic layer was decanted and the solid was washed with dry pentane.
- 25 The washed solid, was dissolved in dry methylene chloride and filtered. Removal of solvents from the filtrate yielded reddish orange solid. A portion of the solid was redissolved in dry methylene chloride, concentrated and cooled to  $-10^\circ\text{C}$ . The precipitated solid was filtered, dried under vacuum and stored under nitrogen. Yield 20-40%.

EXAMPLE 4

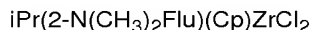
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- [0029]** To a suspension of  $\text{iPr[(2-OCH}_3\text{)Flu)Cp]}$  (1.68 g, 5.6 mmol) in dry THF (50 ml), methyl lithium in ether (1.4 M, 14.0 mmol) was added and stirred at room temperature. The solvents were removed under vacuum and the residue washed with ether/pentane mixture to obtain the dianion as a dark red solid. The subsequent reaction with  $\text{ZrCl}_4$  was performed under conditions described in Example 1.

EXAMPLE 6

- [0030]**  $\text{iPr[(3-OCH}_3\text{)Flu)Cp]}$  was converted to  $\text{iPr[(3-OCH}_3\text{)Flu)Cp]ZrCl}_2$  using the procedure described in Example 2. The crude product was recrystallized from toluene.

45 EXAMPLE 9

- [0031]**  $\text{iPr[(2-N(CH}_3\text{)}_2\text{Flu)Cp]ZrCl}_2$  was prepared from the corresponding ligand according to the procedure described in Example 2.

$\text{iPr(2-OCH}_3\text{Flu)(Cp)ZrCl}_2$  - isopropyl(2-methoxyfluorenyl) (cyclopentadienyl)zirconium dichloride

$\text{iPr(3-OCH}_3\text{Flu)(Cp)ZrCl}_2$  - isopropyl(3-methoxyfluorenyl) (cyclopentadienyl)zirconium dichloride

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$\text{iPr(2-N(CH}_3\text{)}_2\text{Flu)(Cp)ZrCl}_2$  - isopropyl(2-dimethylaminofluorenyl) (cyclopentadienyl)zirconium dichloride

- [0032]** The metallocene catalysts just described are used in combination with an organoaluminum compound as a

co-catalyst. Preferably, the organoaluminum compound is an alumoxane represented by the general formula  $(R-Al-O)_n$  in the cyclic form and  $R(R-Al-O)_nAlR_2$  in the linear form. In the general formula, R is an alkyl group with 1-5 carbons and n is an integer from 1 to about 20. Most preferably, R is a methyl group. Generally, in the preparation of alumoxanes from, for example, trimethyl aluminum and water, a mixture of the linear and cyclic compounds are obtained.

**[0033]** An alternative to the use of the organoaluminum compound is a catalyst system of a metallocene, neutral Lewis acid or ionic ionizing agent and, optionally, an aluminum alkyl. Methods for preparing a cationic metallocene catalyst system are disclosed in European Patent Application Nos. 90870176.6 (Publication no. 0427697A2) and 908701.8 (Publication no. 0426638A2), which are hereby incorporated by reference. The ionizing agent which is an ion pair converts the metallocene to a cation. The metallocene cation forms an ion pair with the anion component of the ionizing agent. The segment of the metallocene compound removed by ionization forms an anion which associates with the cation component of the ionizing agent. The ion pair formed from the anion of the segment of metallocene and the cation of ionizing agent is chemically inert and non-reactive with regard to the metallocene cation and the metallocene cation-ionizing agent anion ion pair which is an active catalyst for polymerization of olefins.

**[0034]** An aluminum alkyl, such as triethylaluminum, is useful in such an ionic catalyst system to improve yields. It is believed that aluminum alkyl acts to enhance the ionizing process and to scavenge catalyst poisons.

**[0035]** The polymerization procedures useful in the present invention include any procedures known in the art. Generally, a metallocene compound as described above is selected, a catalyst is formed using the metallocene compound using any procedure known in the art, including those disclosed above, the catalyst is introduced into a polymerization reaction zone containing an olefin monomer of three or more carbon atoms, the reaction zone is maintained under polymerization reaction conditions and the polymer is extracted from the reaction zone.

**[0036]** In the Examples given below, four different polymerization procedures were utilized. These are just examples of possible polymerization procedures, as any known procedure may be used in practicing the present invention. These procedures, designated as A, B, C and D are described as follows:

## POLYMERIZATION METHODS

### [0037]

**Method A (Bulk polymerization):** The catalyst was dissolved in 5 mL of 10 wt% MAO in toluene, transferred to a stainless steel sample cylinder, and charged with 400 mL of propylene into an autoclave reactor containing 1000 mL of propylene stirring at room temperature. The catalyst was prepolymerized in situ by heating the reactor contents to 60°C within 5 minutes. After stirring at 60°C for one hour, the polymerization was terminated by rapidly venting the unreacted monomer and opening the reactor to the air. The contents of the reactor were dried in a vacuum oven prior to analysis.

**Method B (Slurry polymerization):** The catalyst was dissolved in 2.5 milliliters of MAO. Another 2.5 milliliters of MAO were added to 500 mL of toluene in a reactor. The catalyst solution was transferred to a stainless steel sample cylinder and charged into the reactor, containing the toluene thermostated at 30°C, with 100 psi of propylene. The contents of the reactor were stirred at 30°C for one hour under 100 psi propylene pressure. At the end of this time polymerization was terminated by rapidly venting the reactor of unreacted monomer and opening the reactor to the air. Several hundred milliliters of methanol/4N HCl solution were added to the toluene slurry. The precipitated polymer was collected on a filter funnel and dried in a vacuum oven prior to analysis.

**Method C:** Bulk polymerization of 1.4 liter of propylene similar to Method A except that no MAO is used. Triphenylcarbenium tetrakis(pentafluorophenyl)boronate is used as an ionic ionizing agent to ionize a neutral metallocene and form an ion pair with the metallocene cation.

Triethylaluminum (TEAL) was dissolved in toluene and was added to a 2 liter Zipperclave reactor under 5 psig of nitrogen. One liter of propylene was pumped into the reactor. The mixture was stirred for ten minutes at 1200 rpm. Triphenylcarbenium tetrakis(pentafluorophenyl) boronate was dissolved in 10 ml of toluene. The metallocene was dissolved in 10 ml of toluene. The two solutions were mixed together for 5 minutes at room temperature. The catalyst mixture was added to a stainless steel bomb equipped with ball valves on each end. 400 ml of propylene were pumped through the bomb into the reactor. The contents of the reactor were agitated for sixty minutes. At the end of the polymerization, the reactor was cooled and the unreacted propylene was vented from the reactor. The reaction product was dried under vacuum. The polymer was then weighed and analyzed.

**Method D:** Bulk polymerization of 1.4 liter of propylene similar to Method A except that no MAO is used. N,N-dimethylanilinium tetrakis(pentafluorophenyl)boronate is used as an ionic ionizing agent to ionize a neutral metallocene and form an ion pair with the metallocene cation.

**[0038]** N,N-dimethylaniliniumtetrakis(pentafluorophenyl)boronate was dissolved in 10 ml of toluene. The metallocene was dissolved in 10 ml of toluene. The two solutions were mixed together for 5 minutes at room temperature.

One liter of propylene was pumped into the reactor. The catalyst mixture was added to a stainless steel bomb equipped with ball valves on each end. 400 ml of propylene were pumped through the bomb into the reactor. The contents of the reactor were agitated for sixty minutes. At the end of the polymerization, the reactor was cooled and the unreacted propylene was vented from the reactor. The reaction product was dried under vacuum. The polymer was then weighed and analyzed.

**[0039]** Polymerization results using metallocenes with various substituents are shown in Table I. The polymer product may be analyzed in various ways for differing properties. Particularly pertinent to the present invention are analyses for melting points and molecular weights.

**[0040]** The melting points in the examples below were derived from DSC (Differential Scanning Calorimetry) data as known in the art. The melting points reflected in the tables are not true equilibrium melting points but are DSC peak temperatures on "as-polymerized" samples previously heated to 450°K, held at this temperature for five minutes, and cooled at 10°K/minute with baseline correction. With syndiotactic polypropylene it is not unusual to get an upper and a lower peak temperature, i.e., two peaks, and the data reflects the higher peak melting point.

**[0041]** The molecular weights of the "as polymerized" polymers were calculated using GPC (Gel Permeation Chromatography) analysis and intrinsic viscosity (decaline solutions, 135°C). From GPC,  $M_w$  or the weight molecular weight, and  $M_n$ , number average molecular weight, are obtained.  $M_w$  divided by  $M_n$  is a measurement of the breadth of the molecular weight distribution.

**[0042]** As known in the art, the molecular weight of a polymer is proportional to the rate of propagation of the polymer chain divided by the rate of termination of the chain. A change in the ratio leads to a change in the molecular weights. As described by the present invention, a change in the structure of the catalyst leads to a change in the ratio of the rates of polymerization as well as a change in the melting points of the polymer.

**[0043]** The invention having been generally described, the following table presents particular embodiments of the invention and demonstrates the practice and advantages thereof. It is understood that these embodiments are given by way of illustration and are not intended to limit the specification or the claims to follow in any manner.



TABLE I

| Catalyst<br>(mg) | Substi<br>tuent    | Metal | MAO<br>(ml) | Polymeri-<br>zation<br>Temp (°C) | Time<br>(min) | Yield<br>(g) | Method | Catalyst<br>Efficiency<br>(g/g·hr) | Melting<br>Point<br>(°C) <sup>a</sup> | Molecular<br>Weight* | NMR Data(%) <sup>b</sup><br>mmmm mmrX XmrX rrrr |
|------------------|--------------------|-------|-------------|----------------------------------|---------------|--------------|--------|------------------------------------|---------------------------------------|----------------------|---|
| 2.0              | 2-OCH <sub>3</sub> | Zr    | 5           | 30                               | 60            | 65           | B      | 3,000                              | 134                                   | 103,000(1.37)        | 0 1.1 3.5 82                                    |
| 1.0              |                    |       | 5           | 60                               | 60            | 3            | A      | 3,000                              | 129                                   | 50,000(0.810)        |   |
| 2.0              |                    |       | 5           | 60                               | 60            | 163          | A      | 8,000                              | 117                                   | 69,000(1.02)         | 0 1.7 7.7 75                                    |
| 1.0              | 3-OCH <sub>3</sub> | Zr    | 5           | 30                               | 60            | 30           | B      | 3,000                              | 141                                   | 114,000(1.42)        | 0 1.3 2.0 87                                    |
| 2.0              |                    |       | 5           | 60                               | 60            | 72           | A      | 4,000                              | 131                                   | 72,000(1.05)         | 0 1.8 4.3 82                                    |

Table I (cont.)

| Cata-<br>lyst<br>(mg) | Substituent                        | Metal | MAO<br>(ml) | Polyme-<br>rization<br>Temp<br>(°C) | Time<br>(min) | Yield<br>(g) | Me-<br>thod | Catalyst<br>Efficiency<br>(g/g.hr) | Melting<br>point<br>(°C) | Molecular<br>weight*             | NMR Data (%) |            |            |          |
|-----------------------|------------------------------------|-------|-------------|-------------------------------------|---------------|--------------|-------------|------------------------------------|--------------------------|----------------------------------|--------------|------------|------------|----------|
|                       |                                    |       |             |                                     |               |              |             |                                    |                          |                                  | mmmm         | mmmr       | xmrx       | rrrr     |
| 5.1<br>5.1            | 2-N(CH <sub>3</sub> ) <sub>2</sub> | Zr    | 5<br>5      | 30<br>60                            | 30<br>60      | 4<br>13      | B<br>A      | 800<br>2,500                       | n.d.<br>n.d.             | -<br>-                           | 2.3          | 6.2        | 22         | 18       |
| Comparative example   |                                    |       |             |                                     |               |              |             |                                    |                          |                                  |              |            |            |          |
| 0.65<br>0.56          | H                                  | Zr    | 5<br>5      | 30<br>60                            | 30<br>60      | 22<br>157    | B<br>A      | 68,000<br>28,000                   | 148<br>136               | 147,000 (1.51)<br>115,000 (1.10) | 0<br>0       | 2.4<br>1.1 | 3.0<br>1.1 | 85<br>89 |

\*Gel Permeation Chromatography, intrinsic viscosity value is given in parenthesis in dL/g for a Decalin (decahydronaphthalene) solution at 135°C

a) by DSC, higher of two melting points observed for the polymer is reported.

g) <sup>13</sup>CNMR spectra of the polymers were run at 120°C on Varian VXR3005 spectrometer using 20% (W/W) solutions of the polymers in 1,2,4-trichlorobenzene/d<sub>6</sub>-benzene. The peak analysis and curve fitting was done with NMRI software package.

H - iPr(Flu)(Cp)ZrCl<sub>2</sub> - isopropyl(fluorenyl)(cyclopentadienyl) zirconium dichloride

2-OCH<sub>3</sub> - iPr(2-OCH<sub>3</sub>Flu)(cp)ZrCl<sub>2</sub> - isopropyl(2-methoxyfluorenyl) (cyclopentadienyl)zirconium dichloride

3-OCH<sub>3</sub> - iPr(3-OCH<sub>3</sub>Flu)(Cp)ZrCl<sub>2</sub> - isopropyl(3-methoxyfluorenyl) (cyclopentadienyl)zirconium dichloride

2-N(CH<sub>3</sub>)<sub>2</sub> - iPr(2-N(CH<sub>3</sub>)<sub>2</sub>Flu)(Cp)ZrCl<sub>2</sub> - isopropyl(2-dimethylaminofluorenyl) (cyclopentadienyl)zirconium dichloride

[0044] The results shown in Table I illustrate some of the advantages of the present invention. The compositions and locations of the substituents on the aryl rings of fluorene do have a significant influence on the stereoregularities, melting points and the molecular weights of the polymers. These effects are a result of the steric and electronic properties of the substituents.

[0045] Substituents which are electron donating, either inductively or via resonance, increase the basicity of fluorene in the catalyst. This has been documented in the "J. Org. Chem.", 41, 2391 (1976). It is believed that increasing the basicity of the fluorene ring by substitution increases the catalyst activity. Substituents which increase the basicity of the fluorene ring include alkyl, alkylamino and alkoxy groups.

[0046] The present invention clearly shows that electron donating substituents, for example, dialkylamino, halogen, and alkoxy groups, when present on fluorene at C2 or C3 render the catalyst less active than the unsubstituted complex. The polymers obtained with the catalysts containing these groups also, generally, have lower molecular weights. This behavior of the catalyst is contrary to expectations.

[0047] The Applicants theorize, without limiting the scope of the claims, that the mechanism is due to the Lewis acid-base complexation with the cocatalysts such as either MAO or trimethyl aluminum, which is often present as an impurity in MAO, or [Ph<sub>3</sub>C][B(C<sub>6</sub>F<sub>5</sub>)<sub>4</sub>] or Bronsted acid-base interactions with cocatalysts such as [(C<sub>6</sub>H<sub>5</sub>)N(CH<sub>3</sub>)<sub>2</sub>H][B(C<sub>6</sub>F<sub>5</sub>)<sub>4</sub>]. When the lone pair of electrons on the nitrogen or oxygen atom, directly attached to the fluorene ring are used in complexation to an acidic center, a positive charge is created on the heteroatom. As a consequence, the positive center withdraws electrons away from fluorene thus drastically decreasing its basicity. This results in low polymerization efficiencies and low polymer molecular weights.

[0048] This effect is even more dramatic in the case of iPr[2,7-[N(CH<sub>3</sub>)<sub>2</sub>]<sub>2</sub>Flu)(Cp)ZrCl<sub>2</sub> wherein the lone pairs of electrons on both the nitrogens are tied up in complexation to the cocatalysts, thus suppressing the electron donating (through resonance) ability and increasing the electron withdrawing (through induction) of nitrogen. Similar reasoning can explain decrease in catalyst activities and polymer molecular weights with catalysts containing basic oxygen atoms on C2 or C3 of fluorene.

[0049] Non-coordinating, but weak electron donating substituents, such as alkyl groups, on fluorene are capable of decreasing the basicity of fluorene only slightly. The dimethyl group at C2 and C7 did not affect the catalyst efficiency and molecular weight significantly but the t-butyl group decreased the molecular weight while not decreasing the catalyst activity. The ability of the electron donating substituent to donate electrons must be equal to or greater than that for t-butyl, dimethylamino, chlorine, fluorine or methoxy to decrease the molecular weight.

[0050] While an electron donating substituent, such as alkyl, dialkylamino, halogen or alkoxy, at C2 or C3 of fluorene decreases the catalyst efficiency, the same substituent at C4 not only increased the catalyst efficiency but also dramatically increased the polymer molecular weight. Weak electron donating substituents, such as alkyl or alkoxyalkyl, do not have the same effect. It is theorized, without limiting the scope of the claims, that the heteroatoms when present at C4/C5 on fluorene are in a sterically inaccessible region, thus preventing or minimizing coordination with the cocat-

alyst. The heteroatoms appear to be able to donate electrons through resonance to fluorene thus increasing its basicity and resulting in an increase in molecular weight.

**[0051]** In summary, to increase the catalyst activity and polymer molecular weight, substituents which are either electron donating, non-coordinating groups or heteroatoms bonded to sterically encumbered carbons capable of preventing complexation of the acidic cocatalyst needed to be present on the fluorene ring. Specifically, increased catalyst activity and polymer molecular weights can be realized by substituting fluorene at C4/C5 with heteroatoms capable of electron donation through resonance and decreased catalyst activity and polymer molecular weights can be obtained by/substituting fluorene with electron withdrawing groups. The ability of the electron donating substituent to donate electrons must be equal to or greater than that for methoxy or dimethylamino.

**[0052]** The present invention also addresses the effect of fluorene substituents on the melting point of the polymer. Generally, the melting point of the polymer is a reflection of the tacticity of the polymer. The higher the syndiotacticity of the polymer, the higher is the melting point. Some of the factors which affect the polymer melting point include catalyst and cocatalyst structure and polymerization conditions. Present invention clearly reveals that the stereoregulation during polymerization is strongly influenced by the nature of the substituent, and its location on fluorene.

**[0053]** It is noted that the polymerization temperature is a factor in the formulation of the polymer product. At the lower reaction temperatures, the melting points and molecular weights for the same catalyst were higher. As the reaction temperatures increased, the melting points and the molecular weights decreased. Also, as the reaction temperature increased, the yields and catalyst efficiencies also increased, usually dramatically. However, it is noted that the effect of type and location of substituent is independent of the polymerization temperature.

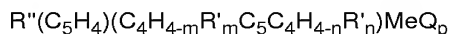
**[0054]** Some of the advantages of the present invention are realized by comparing the polymer properties of Examples using different catalysts but run at the same polymerization temperature. In making these comparisons, it can be seen that the melting points and molecular weights increased when appropriate substituents were in position 4. Also, the molecular weight increased when a Lewis base, such as oxygen, is directly connected to the 4-carbon on the aryl ring. The results show that polymers with lower molecular weights are produced by catalysts with substituents in position other than position 4. Substituents in positions 2 and 7 increased the melting point but decreased the molecular weight. The results clearly show that the melting points and molecular weights can be varied and controlled by changing the substituent groups on the aryl rings of the fluorene ligand.

**[0055]** Obviously, numerous modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described herein.

## Claims

1. A process for polymerizing olefins of three or more carbon atoms to produce a syndiotactic polyolefin comprising:

a) selecting a metallocene compound described by the general formula :



wherein  $(C_5H_4)$  is a cyclopentadienyl ring and  $(C_4H_{4-m}R'_mC_5C_4H_{4-n}R'_n)$  is a fluorenyl radical;  $R'$  is a hydrocarbyl radical, an alkoxy, an alkoxy alkyl or an alkylamino radical having from 1-20 carbon atoms or a halogen, each  $R'$  may be the same or different;  $R''$  is a structural bridge between the  $(C_5H_4)$  and  $(C_4H_{4-m}R'_mC_5C_4H_{4-n}R'_n)$  rings to impart stereorigidity;  $Q$  is a hydrocarbon radical or a halogen;  $Me$  is a Group IIIB, IVB, VB or VIB metal;  $1 \leq m \leq 4$ ;  $0 \leq n \leq 4$ ; and  $p$  is the valence of  $Me$  minus 2;

wherein  $R'$  is an electron donating substituent on the fluorene ligand at C2 or C3 and has the ability to donate electrons equal to or greater than that for t-butyl.

b) forming a catalyst comprising the metallocene compound;

c) introducing the catalyst into a polymerization reaction zone containing an olefin monomer of three or more carbon atoms and maintaining the reaction zone under polymerization reaction conditions; and

d) extracting polymer from the reaction zone.

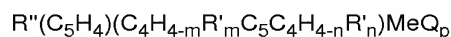
2. A process as recited in Claim 1 wherein  $R'$  is selected from the group consisting of alkyl, dialkylamino, halogen and alkoxy groups.

3. A process as recited in Claim 1 wherein the metallocene compound is selected from the group consisting of isopro-

pyl (2-methoxyfluorenyl) (cyclopentadienyl) zirconium dichloride, isopropyl (3-methoxyfluorenyl) (cyclopentadienyl) zirconium dichloride, and isopropyl (2-dimethylamino fluorenyl) (cyclopentadienyl) zirconium dichloride.

4. A process as recited in Claim 1 wherein R" is an alkylene radical having 1-4 carbon atoms, or arylalkyl or diarylalkyl radical containing 7-20 carbon atoms, a silicon hydrocarbyl compound, a germanium hydrocarbyl compound, an alkyl phosphine, or an alkyl amine.
5. A process as recited in Claim 4 wherein R" is methylene, ethylene, isopropyl, diarylmethyl, an alkyl silicon or a cycloalkyl silicon.
6. A process as recited in Claim 5 wherein R" is isopropyl or diphenylmethyl.
7. A process as recited in Claim 1 wherein Me is a Group IVB metal.
8. A process as recited in Claim 7 wherein Me is selected from the group consisting of zirconium and hafnium.
9. A process as recited in Claim 1 wherein Q is methyl, ethyl, propyl, butyl, amyl, isoamyl, hexyl, isobutyl, heptyl, octyl, nonyl, decyl, cetyl, phenyl, fluorine, chlorine, bromine or iodine.
10. A process as recited in Claim 9 wherein Q is chlorine or methyl.
11. A catalyst system for polymerizing olefins of three or more carbon atoms to produce a syndiotactic polyolefin comprising :

a) a metallocene of the general formula :



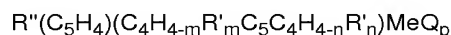
wherein (C<sub>5</sub>H<sub>4</sub>) is a cyclopentadienyl ring and (C<sub>4</sub>H<sub>4-m</sub>R'<sub>m</sub>C<sub>5</sub>C<sub>4</sub>H<sub>4-n</sub>R'<sub>n</sub>) is a fluorenyl radical; R' is a hydrocarbyl radical, an alkoxy, an alkoxy alkyl or an alkylamino radical having from 1-20 carbon atoms or a halogen, each R' may be the same or different; R" is a structural bridge between the (C<sub>5</sub>H<sub>4</sub>) and (C<sub>4</sub>H<sub>4-m</sub>R'<sub>m</sub>C<sub>5</sub>C<sub>4</sub>H<sub>4-n</sub>R'<sub>n</sub>) rings to impart stereorigidity; Q is a hydrocarbon radical or a halogen; Me is a Group IIIB, IVB, VB or VIB metal; 1 ≤ m ≤ 4; 0 ≤ n ≤ 4; and p is the valence of Me minus 2;

wherein R' is an electron donating substituent on the fluorene ligand at C2 or C3 and has the ability to donate electrons equal to or greater than that for t-butyl.

b) a organoaluminum compound of the general formula (R-Al-O) in the cyclic form and R(R-Al-O)<sub>n</sub>AlR<sub>2</sub> in the linear form wherein R is an alkyl group with 1-5 carbons and n is an integer from 1 to 20.

12. A catalyst system as recited in Claim 11 wherein the organoaluminum compound is methylalumoxane.
13. A catalyst system for polymerizing olefins of three or more carbon atoms to produce a syndiotactic polyolefin comprising :

a) a metallocene of the general formula :



wherein (C<sub>5</sub>H<sub>4</sub>) is a cyclopentadienyl ring and (C<sub>4</sub>H<sub>4-m</sub>R'<sub>m</sub>C<sub>5</sub>C<sub>4</sub>H<sub>4-n</sub>R'<sub>n</sub>) is a fluorenyl radical; R' is a hydrocarbyl radical, an alkoxy, an alkoxy alkyl or an alkylamino radical having from 1-20 carbon atoms or a halogen, each R' may be the same or different; R" is a structural bridge between the (C<sub>5</sub>H<sub>4</sub>) and (C<sub>4</sub>H<sub>4-m</sub>R'<sub>m</sub>C<sub>5</sub>C<sub>4</sub>H<sub>4-n</sub>R'<sub>n</sub>) rings to impart stereorigidity; Q is a hydrocarbon radical or a halogen; Me is a Group IIIB, IVB, VB or VIB metal; 1 ≤ m ≤ 4; 0 ≤ n ≤ 4; and p is the valence of Me minus 2;

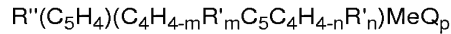
wherein R' is an electron donating substituent on the fluorene ligand at C2 or C3 and has the ability to donate electrons equal to or greater than that for t-butyl.

b) Lewis acid ionizing agent.

14. A catalyst system as recited in Claim 13 wherein the Lewis acid ionic inoizing agent is selected from the group consisting of triphenylcarbenium tetrakis (pentafluorophenyl) boronate and N,N-dimethylanilinium tetrakis(pentafluorophenyl)boronate.

15. A catalyst system as recited in Claim 13 which additionally comprises an aluminum alkyl.

16. A metallocene compound used in a catalyst system for the syndiotactic polymerization of olefins having three or more carbon atoms comprising a metallocene of the general formula :

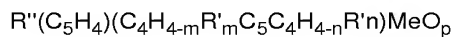


wherein  $(C_5H_4)$  is a cyclopentadienyl ring and  $(C_4H_{4-m}R'_mC_5C_4H_{4-n}R'_n)$  is a fluorenyl radical;  $R'$  is a hydrocarbyl radical, an alkoxy, an alkoxy alkyl or an alkylamino radical having from 1-20 carbon atoms or a halogen, each  $R'$  may be the same or different;  $R''$  is a structural bridge between the  $(C_5H_4)$  and  $(C_4H_{4-m}R'_mC_5C_4H_{4-n}R'_n)$  rings to impart stereorigidity;  $Q$  is a hydrocarbon radical or a halogen;  $Me$  is a Group IIIB, IVB, VB or VIB metal;  $1 \leq m \leq 4$ ;  $0 \leq n \leq 4$ ; and  $p$  is the valence of  $Me$  minus 2; wherein  $R'$  is an electron donating substituent on the fluorene ligand at C2 or C3 and has the ability to donate electrons equal to or greater than that for t-butyl.

## Patentansprüche

1. Verfahren zum Polymerisieren von Olefinen von drei oder mehreren Kohlenstoffatomen unter Herstellen eines syndiotaktischen Polyolefins, umfassend:

a) Auswählen einer Metallocenverbindung, beschrieben durch die allgemeine Formel:



wobei  $(C_5H_4)$  ein Cyclopentadienylring ist, und  $(C_4H_{4-m}R'_mC_5C_4H_{4-n}R'_n)$  ist ein Fluorenylrest,  $R'$  ist ein Hydrocarbylrest, ein Alkoxy-, ein Alkoxyalkyl- oder ein Alkylaminorest mit 1-20 Kohlenstoffatomen oder ein Halogen, jedes  $R'$  kann gleich oder unterschiedlich sein,  $R''$  ist eine Strukturbrücke zwischen den  $(C_5H_4)$  und  $(C_4H_{4-m}R'_mC_5C_4H_{4-n}R'_n)$  Ringen zum Verleihen von Stereorigidität,  $Q$  ist ein Kohlenwasserstoffrest oder ein Halogen,  $Me$  ist ein Gruppe IIIB, IVB, VB oder VIB Metall,  $1 \leq m \leq 4$ ,  $0 \leq n \leq 4$ , und  $p$  ist die Wertigkeit von  $Me$  minus 2, wobei  $R'$  ein Elektronen gebender Substituent auf dem Fluorenyliganden bei C2 oder C3 ist und die Fähigkeit hat, Elektronen gleich oder größer als das für t-Butyl zu geben,

b) Bilden eines Katalysators, umfassend die Metallocenverbindung,

c) Einführen des Katalysators in eine Polymerisationsreaktionszone, enthaltend ein Olefinmonomer von drei oder mehreren Kohlenstoffatomen, und Beibehalten der Reaktionszone unter Polymerisationsreaktionsbedingungen, und

d) Extrahieren von Polymer aus der Reaktionszone.

2. Verfahren nach Anspruch 1, wobei  $R'$  aus der Gruppe, bestehend aus Alkyl-, Dialkylamino-, Halogen- und Alkoxygruppen ausgewählt wird.

3. Verfahren nach Anspruch 1, wobei die Metallocenverbindung aus der Gruppe, bestehend aus Isopropyl(2-methoxyfluorenyl)(cyclopentadienyl)zirconiumdichlorid, Isopropyl(3-methoxyfluorenyl)(cyclopentadienyl)zirconiumdichlorid und Isopropyl(2-dimethylaminofluorenyl)(cyclopentadienyl)zirconiumdichlorid ausgewählt wird.

4. Verfahren nach Anspruch 1, wobei  $R''$  ein Alkylenrest mit 1-4 Kohlenstoffatomen oder Arylalkyl- oder Diarylalkylrest, enthaltend 7-20 Kohlenstoffatome, eine Siliciumhydrocarbylverbindung, eine Germaniumhydrocarbylverbindung, ein Alkylphosphin oder ein Alkylamin ist.

5. Verfahren nach Anspruch 4, wobei  $R''$  Methylen, Ethylen, Isopropyl, Diarylmethyl, ein Alkylsilicium oder ein Cycloalkylsilicium ist.

6. Verfahren nach Anspruch 5, wobei  $R''$  Isopropyl oder Diphenylmethyl ist.

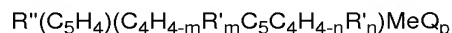
7. Verfahren nach Anspruch 1, wobei  $Me$  ein Gruppe IVB Metall ist.

8. Verfahren nach Anspruch 7, wobei Me aus der Gruppe, bestehend aus Zirkonium und Hafnium, ausgewählt wird.
9. Verfahren nach Anspruch 1, wobei Q Methyl, Ethyl, Propyl, Butyl, Amyl, Isoamyl, Hexyl, Isobutyl, Heptyl, Octyl, Nonyl, Decyl, Cetyl, Phenyl, Fluor, Chlor, Brom oder Jod ist.

10. Verfahren nach Anspruch 9, wobei Q Chlor oder Methyl ist.

11. Katalysatorsystem zum Polymerisieren von Olefinen von drei oder mehreren Kohlenstoffatomen unter Herstellen eines syndiotaktischen Polyolefins, umfassend:

- a) ein Metallocen der allgemeinen Formel:



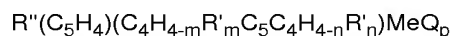
wobei  $(C_5H_4)$  ein Cyclopentadienylring ist, und  $(C_4H_{4-m}R'_mC_5C_4H_{4-n}R'_n)$  ist ein Fluorenylrest,  $R'$  ist ein Hydrocarbylrest, ein Alkoxy-, ein Alkoxyalkyl- oder ein Alkylaminorest mit 1-20 Kohlenstoffatomen oder ein Halogen, jedes  $R'$  kann gleich oder unterschiedlich sein,  $R''$  ist eine Strukturbrücke zwischen den  $(C_5H_4)$  und  $(C_4H_{4-m}R'_mC_5C_4H_{4-n}R'_n)$  Ringen zum Verleihen von Stereorigidität,  $Q$  ist ein Kohlenwasserstoffrest oder ein Halogen,  $Me$  ist ein Gruppe IIIB, IVB, VB oder VIB Metall,  $1 \leq m \leq 4$ ,  $0 \leq n \leq 4$ , und  $p$  ist die Wertigkeit von  $Me$  minus 2, wobei  $R'$  ein Elektronen gebender Substituent auf dem Fluorenyliganden bei C2 oder C3 ist und die Fähigkeit hat, Elektronen gleich oder größer als das für t-Butyl zu geben,

b) eine Organoaluminiumverbindung der allgemeinen Formel  $(R-Al-O)$  in der zyklischen Form und  $R(R-Al-O)_nAlR_2$  in der linearen Form, wobei  $R$  eine Alkylgruppe mit 1-5 Kohlenstoffatomen ist, und  $n$  ist eine ganze Zahl von 1 bis 20.

12. Katalysatorsystem nach Anspruch 11, wobei die Organoaluminiumverbindung Methylalumoxan ist.

13. Katalysatorsystem zum Polymerisieren von Olefinen von drei oder mehreren Kohlenstoffatomen unter Herstellen eines syndiotaktischen Polyolefins, umfassend:

- a) ein Metallocen der allgemeinen Formel:



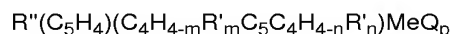
wobei  $(C_5H_4)$  ein Cyclopentadienylring ist, und  $(C_4H_{4-m}R'_mC_5C_4H_{4-n}R'_n)$  ist ein Fluorenylrest,  $R'$  ist ein Hydrocarbylrest, ein Alkoxy-, ein Alkoxyalkyl- oder ein Alkylaminorest mit 1-20 Kohlenstoffatomen oder ein Halogen, jedes  $R'$  kann gleich oder unterschiedlich sein,  $R''$  ist eine Strukturbrücke zwischen den  $(C_5H_4)$  und  $(C_4H_{4-m}R'_mC_5C_4H_{4-n}R'_n)$  Ringen zum Verleihen von Stereorigidität,  $Q$  ist ein Kohlenwasserstoffrest oder ein Halogen,  $Me$  ist ein Gruppe IIIB, IVB, VB oder VIB Metall,  $1 \leq m \leq 4$ ,  $0 \leq n \leq 4$ , und  $p$  ist die Wertigkeit von  $Me$  minus 2, wobei  $R'$  ein Elektron gebender Substituent auf dem Fluorenyliganden bei C2 oder C3 ist und die Fähigkeit hat, Elektronen gleich oder größer als das für t-Butyl zu geben,

b) ein Lewissäureionisierungsmittel.

14. Katalysatorsystem nach Anspruch 13, wobei das Lewissäure ionische Ionisierungsmittel ausgewählt ist aus der Gruppe, bestehend aus Triphenylcarbeniumtetrakis(pentafluorphenyl)boronat und N,N-Dimethylaniliniumtetrakis(pentafluorphenyl)boronat.

15. Katalysatorsystem nach Anspruch 13, welches zusätzlich ein Aluminiumalkyl umfaßt.

16. Metallocenverbindung, verwendet in einem Katalysatorsystem für die syndiotaktische Polymerisation von Olefinen mit drei oder mehreren Kohlenstoffatomen, umfassend ein Metallocen der allgemeinen Formel:



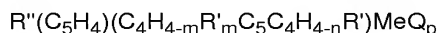
wobei  $(C_5H_4)$  ein Cyclopentadienylring ist, und  $(C_4H_{4-m}R'_mC_5C_4H_{4-n}R'_n)$  ist ein Fluorenylrest,  $R'$  ist ein Hydrocarbylrest, ein Alkoxy-, ein Alkoxyalkyl- oder ein Alkylaminorest mit 1-20 Kohlenstoffatomen oder ein Halogen, jedes  $R'$  kann gleich oder unterschiedlich sein,  $R''$  ist eine Strukturbrücke zwischen den  $(C_5H_4)$  und  $(C_4H_{4-m}R'_mC_5C_4H_{4-n}R'_n)$  Ringen zum Verleihen von Stereorigidität,  $Q$  ist ein Kohlenwasserstoffrest oder ein Halogen,  $Me$  ist ein Gruppe

IIIB, IVB, VB oder VIB Metall  $1 \leq m \leq 4$ ,  $0 \leq n \leq 4$ , und p ist die Wertigkeit von Me minus 2, wobei R' ein Elektron gebender Substituent auf dem Fluorenliganden bei C2 oder C3 ist und die Fähigkeit hat, Elektronen gleich oder größer als das für t-Butyl zu geben.

## 5 Revendications

1. Un procédé pour polymériser des oléfines de trois ou davantage d'atomes de carbone pour produire une polyoléfine syndiotactique comprenant:

10 a) choisir un composé de métallocène décrit par la formule générale:



15 où  $(C_5H_4)$  est un anneau cyclopentadiényle et  $(C_4H_{4-m}R'_mC_5C_4H_{4-n}R'_n)$  est un radical fluorényle; R' est un radical hydrocarbyle, un alkoxy, un alkoxyalkyle ou un radical alkylamino ayant de 1-20 atomes de carbone ou un halogène, chaque R' peut être identique ou différent, R'' est un pont structurel entre les anneaux  $(C_5H_4)$  et  $(C_4H_{4-m}R'_mC_5C_4H_{4-n}R'_n)$  pour communiquer une stéréorigidité; Q est un radical hydrocarbyle ou un halogène; Me est un métal du groupe IIIB, IVB, VB ou VIB;  $1 \leq m \leq 4$ ;  $0 \leq n \leq 4$  et p est la valence de Me moins 2;

20 où R' est un substituant donneur d'électrons au ligand fluorène en C2 ou C3 et a la capacité de donner des électrons égale ou supérieure à celle pour le t-butyle.

b) former un catalyseur comprenant un composé de métallocène;

25 c) introduire le catalyseur dans une zone de réaction de polymérisation contenant un monomère d'oléfine de trois ou davantage d'atomes de carbone et maintenir la zone de réaction sous des conditions de réaction de polymérisation et

d) extraire le polymère de la zone de réaction.

2. Un procédé selon la revendication 1 dans lequel R' est choisi dans le groupe consistant en groupes alkyle, dialkylamino, halogène et alkoxy.

3. Procédé selon la revendication 1 dans lequel le composé de métallocène est choisi dans le groupe consistant en dichlorure d'isopropyl (2-méthoxyfluorényle) (cyclopentadiényle) zirconium, dichlorure d'isopropyl (3-méthoxyfluorényle) (cyclopentadiényle) zirconium, et dichlorure d'isopropyl (2-diméthylaminofluorényle) (cyclopentadiényle) zirconium.

4. Procédé selon la revendication 1 dans lequel R'' est un radical alkyle ayant de 1-4 atomes de carbone, ou un radical arylalkyle ou diarylalkyle contenant 7-20 atomes de carbone, un composé d'hydrocarbyl silicium, un composé d'hydrocarbyl germanium, une alkylphosphine ou une alkylamine.

5. Un procédé selon la revendication 4 dans lequel R'' est le méthylène, l'éthylène, un isopropyle, diarylméthyle, un alkyl silicium ou un cycloalkyl silicium.

6. Un procédé selon la revendication 5 dans lequel R'' est l'isopropyle ou diphénylméthyle.

7. Un procédé selon la revendication 1 dans lequel Me est un métal du groupe IVB.

8. Un procédé selon la revendication 7 dans lequel Me est choisi dans le groupe consistant en zirconium et hafnium.

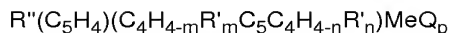
9. Un procédé selon la revendication 1 dans lequel Q est un méthyle, éthyle, propyle, butyle, amyle, isoamyle, hexyle, isobutyle, heptyle, octyle, nonyle, décyle, cétyle, phényle, fluore, chlore, brome ou iode.

10. Un procédé selon la revendication 9 dans lequel Q est le chlore ou un méthyle.

11. Un système de catalyseur pour la polymérisation d'oléfines de trois ou davantage d'atomes de carbone pour produire une polyoléfine syndiotactique comprenant:

a) un métallocène de la formule générale:





où  $(C_5H_4)$  est un anneau cyclopentadiényle et  $(C_4H_{4-m}R'_mC_5C_4H_{4-n}R'_n)$  est un radical fluorényle;  $R'$  est un radical hydrocarbyle, un alkoxy, un alkoxyalkyle ou un radical alkylamino ayant de 1-20 atomes de carbone ou un halogène, chaque  $R'$  peut être identique ou différent;  $R''$  est un pont structurel entre les anneaux  $(C_5H_4)$  et  $(C_4H_{4-m}R'_mC_5C_4H_{4-n}R'_n)$  pour communiquer une stéréorigidité;  $Q$  est un radical hydrocarbure ou un halogène;  $Me$  est un métal du groupe IIIB, IVB, VB ou VIB;  $1 \leq m \leq 4$ ;  $0 \leq n \leq 4$  et  $p$  est la valence de  $Me$  moins 2;

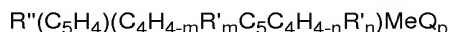
où  $R'$  est un substituant donneur d'électrons sur le ligand fluorène en C2 ou C3 et a la capacité de donner des électrons égale ou supérieure à celle pour le t-butyle.

b) un composé d'organoaluminium de la formule générale  $R-Al-O$  sous forme cyclique et  $R(R-Al-O)_nAlR_2$  sous forme linéaire où  $R$  est un groupe alkyle de 1-5 atomes de carbone et  $n$  est un nombre entier de 1 à 20.

12. Un système de catalyseur selon la revendication 11 dans lequel le composé d'organoaluminium est le méthylalumoxane.

13. Un système de catalyseur pour polymériser des oléfines de trois ou davantage d'atomes de carbone pour produire une polyoléfine syndiotactique comprenant:

a) un métallocène de la formule générale:



où  $(C_5H_4)$  est un anneau cyclopentadiényle et  $(C_4H_{4-m}R'_mC_5C_4H_{4-n}R'_n)$  est un radical fluorényle;  $R'$  est un radical hydrocarbyle, un alkoxy, un alkoxyalkyle ou un radical alkylamino ayant de 1-20 atomes de carbone ou un halogène, chaque  $R'$  peut être identique ou différent;  $R''$  est un pont structurel entre les anneaux  $(C_5H_4)$  et  $(C_4H_{4-m}R'_mC_5C_4H_{4-n}R'_n)$  pour communiquer une stéréorigidité;  $Q$  est un radical hydrocarbure ou un halogène;  $Me$  est un métal du groupe IIIB, IVB, VB ou VIB;  $1 \leq m \leq 4$ ;  $0 \leq n \leq 4$ ; et  $p$  est la valence de  $Me$  moins 2;

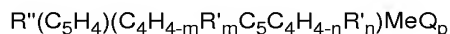
où  $R'$  est un substituant donneur d'électrons sur le ligand fluorène en C2 ou C3 et a la capacité de donner des électrons égale ou supérieure à celle pour le t-butyle.

b) un agent d'ionisation d'acide de Lewis.

14. Un système de catalyseur selon la revendication 13 dans lequel l'agent d'ionisation ionique d'acide de Lewis est choisi dans le groupe consistant en tétrakis (pentafluorophényl)boronate de triphénylcarbénium et tétrakis(pentafluorophényl)boronate de N,N-diméthylanilinium.

15. Un système de catalyseur selon la revendication 13 qui en outre comprend un alkylaluminium.

16. Un composé de métallocène utilisé dans un système de catalyseur pour la polymérisation syndiotactique d'oléfines ayant trois ou davantage d'atomes de carbone comprenant un métallocène de la formule générale:



où  $(C_5H_4)$  est un anneau cyclopentadiényle et  $(C_4H_{4-m}R'_mC_5C_4H_{4-n}R'_n)$  est un radical fluorényle;  $R'$  est un radical hydrocarbyle, un alkoxy, un alkoxyalkyle ou un radical alkylamino ayant de 1-20 atomes de carbone ou un halogène, chaque  $R'$  peut être identique ou différent,  $R''$  est un pont structurel entre les anneaux  $(C_5H_4)$  et  $(C_4H_{4-m}R'_mC_5C_4H_{4-n}R'_n)$  pour communiquer une stéréorigidité;  $Q$  est un radical hydrocarbure ou un halogène;  $Me$  est un métal du groupe IIIB, IVB, VB ou VIB;  $1 \leq m \leq 4$ ;  $0 \leq n \leq 4$ ; et  $p$  est la valence de  $Me$  moins 2; où  $R'$  est un substituant donneur d'électrons sur le ligand fluorène en C2 ou C3 et a la capacité de donner des électrons égale ou supérieure à celle pour le t-butyle.